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The Resolving Powers of X-Ray Spectrometers and the Tungsten X-Ray Spectrum: Elmer Dershem, Department of Physics, University of Illinois. The theory of resolving power is given with the results of experiments on tungsten, in which the endeavor was made to obtain as high a resolving power as possible.

Note on Methods of Observing Potential Differences Induced by the Earth's Magnetic Field in an Insulated Moving Wire: Carl Barus and Maxwell Barus, Department of Physics, Brown University. A simple apparatus is described, and an elementary estimate first given. The apparatus was then modified, producing intensification, and new observations were made.

Dependence of the Spectral Relation of Double Stars upon Distance: C. D. Perrine, Observatorio Nacional Argentino, Cordoba. There is an indication that some external cause is operating in more or less definite regions of our stellar system upon the conditions which produce spectral class.

Hypothesis to Account for the Spectral Conditions of the Stars: C. D. Perrine, Observatorio Nacional Argentino, Cordoba. The spectral condition of a star depends chiefly upon its size and mass and the external conditions of density of cosmical matter and relative velocities of star and matter.

National Research Council: Minutes of the thirty-fourth, thirty-fifth and thirty-sixth meetings of the Committee; war organization of the National Research Council.

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SPECIAL ARTICLES

TERNARY SYSTEMS AND THE BEHAVIOR OF PROTOPLASM

I

IN order to define more accurately the nature of certain changes which are observed in protoplasm (its normal water content, edema, cloudy swelling, fatty degeneration, necrosis) we have been continuing our study of the be-

havior of various simple colloids so far as their powers of hydration and dehydration are concerned under the influence of changes in their surroundings. Since the chemistry of the proteins is rather complicated, we have turned to a study of the colloid behavior of the chemically simpler soaps, for these show close analogy in their processes of hydration and dehydration to certain proteins. The soaps, however, behave in their turn much like mutually soluble systems of the type phenol-water-salt, and so we have passed from a study of the soaps to a study of these simpler physico-chemical systems. From these we have then built backwards through the soaps to the proteins and from these to the properties of living cells. The study as a whole makes clearer, we think, the nature of various changes which are observed in living matter. Many of the "vital" phenomena of cells may be interpreted in the terms of the behavior of simple hydrophilic colloids. These in turn, may be interpreted as expressions of the changes to be observed in systems of mutually soluble materials (like two liquids and a solid, a liquid and two solids, etc.) more particularly the changes incident to their "separation" in their "critical realms" with the accompanying changes in viscosity, in light transmission, in state of "solvent" or "dissolved" substances, etc.

II

Our studies on soaps not only corroborate the work of various well-known authors (Hofmeister, Lewkowitch, Krafft, Merklen, Goldschmidt, Botazzi, Victorow and Leimdörfer), but amplify their studies in that we worked with pure (salt-free) soaps and with longer series of such while subjecting them to more widely varying external conditions than is the case in most of the investigations thus far reported.

We began with the preparation of equimolar amounts of various salt-free soaps in the presence of a definite volume of water. For this purpose we neutralized (at the temperature of boiling water) the proper fatty acid with an equivalent of the proper alkali in a unit volume of water. When not otherwise speci-

fied, our standard soap mixtures contain the proportions represented by a mol of the fatty acid neutralized by the gram equivalent of the proper metallic hydroxide, oxide or carbonate in the presence of a little water.

As long known from empiric practise, the different soaps bind totally different quantities of water. We first determined the absolute amounts of water that are absorbed by equimolar amounts of different *oleates* when prepared as described above. If that capable of holding most water is named first, the order in which these different soaps absorb water is about as follows; potassium, sodium, ammonium (?), lithium, magnesium, calcium, lead, mercury. Under the conditions of our experiments the first four bind all the water offered them (several hundred per cent.). Magnesium, however, holds but sixty per cent. its weight of water, and calcium oleate but forty. Even lower figures (about 10 per cent.) are obtained for the oleates of mercury and lead.

This general order in which the oleates with different basic radicals hold water is repeated by the *palmitates*, *margarates* and *stearates*. If the amount of water used in the preparation of the molar equivalents of soap is sufficiently reduced (to one fourth that stated above) then this same order may also be discovered in the case of the *caprylates*. These general findings seem therefore to justify the conclusion that *a first factor in the determination of the amount of water held by any soap resides in the nature of the basic radical combined with the fatty acid*.

We tried next to determine the effect of combining the same basic radical with different fatty acids of the same series. In these experiments we again neutralized one mol of the fatty acid with an equivalent of the necessary base (sodium or potassium hydroxide) in the presence of a constant volume (one liter) of water. The absolute amount of water taken up by a mol of any of these salts, as determined by discovering the maximum amount of water which such will take up at room temperature and yield a stiff jelly, increases progressively with the increase in the

molecular weight of the fatty acid used. The absolute amounts of water absorbed vary enormously. From the lower members of the series (from the formates through the caproates) no colloid jellies at all can be obtained. The crossing line is well marked by sodium or potassium caprylate. These soaps form clear (molecular) solutions in twice their weight of water but they form jellies with once their weight of water. The amount of water that will be thus taken up and yield a jelly increases progressively as acids above caprylic are used so that by the time stearic acid is reached, one part of soap will easily take up a hundred or even two hundred times its weight of water and form a solid mass. Experiments with fatty acids beyond stearic are not yet completed. Obviously then, with a given base, *a second element in the amount of water held by a soap depends upon the nature of the fatty acid contained in the soap and its height in the series*.

We tried next the effects of different alkalies, of different neutral salts and of different non-electrolytes upon the hydration capacity of different soaps (caprylates, laurates, oleates, palmitates, margarates and stearates of sodium and potassium). Our conclusions under this head may be summed up as follows:

1. The addition of any *alkali* to a "solution" of any of these soaps at first increases its viscosity or (in a limited volume of water) leads to its gelation; with higher concentration of the added alkali, there follows a decrease in viscosity ("liquefaction") which change is succeeded, at sufficiently high concentration of the alkali by complete separation of the soap from the dispersion medium as a dry mass floating upon the "solvent." When equimolar solutions of the different soaps are compared it is found that the effects of an added alkali vary with (a) the fatty acid in the soap, (b) the base combined with the soap and (c) the basic radical of the added alkali. The lowermost members of the fatty acid series neither gel nor come out of "solution" upon addition of an alkali. The caprylates gel and come out easily while the higher soaps show these changes in increasingly marked

degree. When potassium and sodium soaps are compared, it is found that an added alkali will produce the series of changes earlier in a sodium soap than in a potassium soap. Similarly, if the effects are compared of adding equinormal solutions of potassium or sodium hydroxide to a given soap the former is found not so effective (in other words, a higher concentration is demanded to produce the series of changes noted above) as the latter. When solutions of the hydroxides of the bivalent or trivalent metals are used, the effects of the metallic radicals and the formation of metallic soaps with their low hydration capacity dominate the picture. Such hydroxides, therefore, lead uniformly only to decrease in viscosity and separation of the slightly hydrated soap from the dispersion mediums.

2. The addition of *salts* of the bivalent and trivalent metals to potassium, sodium, ammonium and lithium soaps leads to a clouding of the mixtures, a decrease in viscosity and a decrease in power to gel. The picture is again dominated, in other words, by the production of the metallic soaps with their low hydration capacities. A more careful study of the hydration and dehydration of the soaps of the alkali metals under the influence of various salts is therefore, limited to the salts of the alkali metals. As generally known in technological practise, these salts lead to a "salting out" of the soap, or, when used in smaller amounts, to a "gumming" or "stringing" of the soap. We were able to confirm and amplify here the investigations of other workers in this field which have shown that such gumming and ultimate salting out are dependent upon the concentration and the chemical nature of the salt used. With rare exceptions (more particularly those salts which in aqueous solutions are not "neutral") all the ordinary salts of potassium, sodium, lithium, etc., at first increase the viscosity of a potassium or sodium soap to a point where at proper concentration a soap jelly results, beyond which further increase leads to a fall in viscosity (liquefaction) until, in still higher concentrations of the salt, the soap begins to

separate from its clear dispersion medium, at first as a cloudy jelly and then as a (practically dry) dehydrated soap mass swimming upon the clear "solvent."

The intensity with which these successive changes are brought about again varies, at the same concentration of salt, with the fatty acid in the soap, the nature of the basic radical in the soap and the basic radical of the salt used. Potassium salts, for example, are less effective in bringing about the series of changes than the corresponding sodium or lithium salts.

The acid radical (fluoride, chloride, bromide, iodide, nitrate, sulphocyanate, sulphate, acetate, tartrate, citrate) in the series employed by us seems to influence the end results so little as to come within the limits of experimental error. In other words, with salts of a given base the acid radical is practically of immaterial importance.

When *an alkali and a salt are together added* to a soap, the action of the two is found to be algebraically additive. An alkalized soap may be salted out by adding a neutral salt and at a concentration of the latter which would not by itself have proved effective. Vice versa, a partially salted soap may be completely dehydrated by adding an alkali to a concentration at which the alkali alone would have produced no such effect.

It is also of interest that all these effects of alkali, of salts, etc., are largely reversible. A soap dehydrated by an alkali or a salt can be rehydrated by merely adding water; a soap partially dehydrated by a sodium salt can be rehydrated by substituting a potassium salt, etc. Most interesting, however (and physiologically important), is the fact that magnesium, calcium and even iron and copper soaps can, through the addition of the proper salts or hydroxides of the alkali metals, be slowly brought back into the more highly hydrated soaps of these alkali metals.

3. The *non-electrolytes* (alcohol, glycerin, dextrose, saccharose, lactose, urea) as compared with the electrolytes have at the same concentration relatively little effect upon the hydration and dehydration of soaps. They

tend in general to inhibit that series of changes which may be brought about in soaps through a lowering of temperature, the addition of alkali, the addition of salt, etc.

These findings indicate, therefore, that *a third element in the hydration and dehydration of soaps is resident in the kind and concentration of various alkalies, salts or non-electrolytes which may be present in the system.*

Great care is necessary before it is assumed that in order to understand the behavior of any *mixture of soaps* it is only necessary to compound the behavior of the individual pure soaps. The higher fatty acids uniformly yield soaps of the highest absolute hydration capacity, and yet if mixtures of a higher fatty acid soap and one lower in the series are prepared at the temperature of boiling water, the physical properties of the system on cooling are dominated by those characteristic of the *lower fatty acid soaps*. A hydrated sodium or potassium stearate, margarate or palmitate which at room temperature is absolutely solid becomes only viscid or remains distinctly liquid when small amounts of the caprylates, laurates or oleates are mixed with the stearate.

III

It must first be pointed out that *all the laws here emphasized as governing the hydration and dehydration of soaps are identical with those which govern the hydration and dehydration of certain proteins (like the globulins)*. Whatever is the ultimately accepted theory of the nature of the action of the elements enumerated above in producing hydration and dehydration ("precipitation") in soaps, this will also prove to be the accepted one for this class of proteins. As the soaps (but not the fatty acids) are "soluble" in water so also are the alkalized globulins (but not neutral globulin). As low concentrations of the alkali metals favor the hydration of soaps, thus also do they favor the hydration of globulin; on the other hand, as these same salts in higher concentrations "salt out" the former, so also do they salt out the latter. As the heavy metals, whether added as hydroxide or as salt,

yield sparsely hydrated metallic soaps, so also do they yield sparsely hydrated globulins. As reversion of hydration or dehydration in soaps is easy when the salts of the alkali metals are involved, becomes increasingly difficult with magnesium and calcium compounds and proves only partially successful and then only after a long time when salts of the heavy metals are used, so also are the analogous reversions easy or difficult in the case of the globulins.

IV

To explain these changes in soaps, in various proteins and in living cells which have been subjected to similar changes in their surroundings we turn to the changes which may be seen in mutually soluble systems of the type phenol-water-salt as studied by Friedländer and his followers and as variously considered as of importance for an understanding of the changes in colloids¹ by Hardy, Höber, Wolfgang Ostwald and Hatschek.

Thus, water is soluble in phenol and phenol in water; similarly, water is soluble in soap and soap in water. The maximum viscosity of a phenol-water mixture appears in the critical realm when, under changes in surroundings or composition, phenolated water "separates out" in hydrated phenol or hydrated phenol appears in phenolated water. Soaps, similarly, show a maximum viscosity when a proper hydrated soap is produced in soap water or soap water separates out in hydrated

¹ We accept as the correct definition of "colloid," the dispersion of one material in a second, the degree of dispersion being less than that represented by the molecular degree of subdivision characteristic of "true" solutions. Limiting ourselves to the groups of dispersoids represented by solid-liquid and liquid-liquid mixtures (those of chief interest, biologically) we do not think that the former yield always suspensoids and the latter emulsoids, but that *either* type may result. (Liquid) mercury in water or (liquid) oil in water yield suspensoids while (solid) ferric hydroxide or crystallized albumin in water yield emulsoids. *The emulsoids result when each of the phases is soluble in the other; the suspensoids when not more than one of the phases is soluble in the other.*

soap. When an alkali or a salt is added to a phenol-water or to a soap-water system the "solubility" of each of the three phases in the remaining two changes. A clear "solution" of phenol, water and salt (at definite temperature) can be obtained only at proper concentrations of these three materials. Changes in any of them lead to changes in viscosity, changes in optical properties, changes in the distribution of one or more of the "dissolved" substances in the other phases, etc. This is also true of soap and individual proteins as discussed above and of protoplasm under physiological and pathological circumstances as noted in our earlier papers. What happens depends upon the chemical nature of the original substances entering into the mutually soluble system, their concentration and the temperature.

Applied to protoplasm we incline to the view that this consists of a series of hydrophilic (protein) colloids which have sucked up ("dissolved") a certain amount of water and a certain amount of various salts. The system is not unlike phenol saturated with water and containing "dissolved" in it various electrolytes and non-electrolytes. We hope to discuss in detail later, older experiments and our own which show how, at constant temperature, physical and chemical variation in any one of the substances in such simple systems is followed by change in the remaining ones and this in a fashion identical with certain changes observed in protoplasm. These mutually soluble physico-chemical systems show a normal water content (normal turgor) which may be decreased (cell shrinkage, plasmoptysis) or increased (plasmolysis, edema); accompanying such there are changes in viscosity (drying or swelling of tissues), changes in optical properties ("cloudy" swelling) and changes in distribution of dissolved substances ("vital" absorption or secretion). These changes in physico-chemical systems or in protoplasm may be brought about by changing (1) the fundamental type of the substrate itself (as when calcium or magnesium proteinate is substituted for potassium or sodium proteinate), by changing (2) the concentration

of the electrolytes or non-electrolytes acting upon the substrate (either by increasing the amount of an alkaline metal in a cell, or by adding so much that it combines with the water of the cell and leads to protoplasmic dehydration through deprivation of "solvent" as first brought out by Hofmeister), or by changing (3) the chemical character of the salt acting upon the substrate (as when magnesium or iron salts are used instead of salts of the alkali metals). Some of these changes are reversible (like those produced by alkalies or alkali metals, in which case the corresponding tissue changes, as "edema" or "cloudy swelling," are also reversible), while others are not (in which case the changes in protoplasm, like the effects of a heavy metal, are also irreversible or incurable, and the involved tissues are said to suffer "death" or "necrosis").

The effect of changes in temperature upon these ternary (or more complicated) physico-chemical systems is also analogous to the effect of temperature upon protoplasm. As mutual "solubility" may increase or decrease with increase in temperature, a change in the system may occur in one or the other direction. The clearing of a turbid soap-water-salt or a globulin-water-salt system when the temperature is raised illustrates the one type of reaction, the "coagulation" of an albumin the other.

v

This more detailed study on soaps has enabled us also to study further and to *verify our earlier contentions regarding the conditions which make for the maintenance and the breaking of emulsions*. We have previously emphasized that oil can not be emulsified in water to yield an oil-in-water type of emulsion containing more than a fraction of one per cent. of fat, except as a colloid substance is present which unites with the water and forms a colloid hydrate. The truth of this general statement is verified by using as emulsifying agents the soaps described above. The lowermost members of the fatty acid series (which in water form only molecular solutions) do not make emulsification at all pos-

sible. The caprylates, which are the first in the series to show distinct hydrophilic properties, are good emulsifying agents, and, generally speaking, the value of these emulsifying agents increases steadily as we mount in the fatty acid series. An upper optimum is shown by those soaps which (like sodium stearate) are brittle and "dry" at ordinary temperatures. But the potassium soaps of these higher fatty acids are all good emulsifiers as are even the sodium soaps if the temperature is increased whereby the brittle, crystalline, colloid hydrates formed at lower temperatures are converted into more tenacious colloids which bear stretching into thin layers without rupture.

How important is the degree of hydration of the soap for thus stabilizing the emulsions is also well shown when the effects are studied of adding an alkaline salt in progressively higher concentrations to one of the more liquid soaps (like sodium oleate, sodium caprylate, sodium laurate or potassium palmitate, margarate, or stearate). As previously noted, the hydration capacity of the soaps is increased at first, decreased later and finally reduced to zero. Similarly the emulsifying power of the soap at first increases then decreases and finally becomes zero.

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June 15, 1918

FIELD CONFERENCE OF CEREAL PATHOLOGISTS

THE fourth Annual Conference of Cereal Pathologists was held at Purdue University, Lafayette, Ind., beginning June 19 and ending Friday afternoon, June 21. Forty names were signed to the register. A tentative program was presented as a guide for discussion, although no formal program had been prepared in advance. This fact helped to make the meetings more informal and all discussions were in the nature of round-table talks. Certain members were asked to lead in the discussion upon topics in which they were especially interested.

8:30 A.M., June 19—24 Present.

Professor H. P. Barss called the conference to order and after a few introductory remarks the program was taken up.

Barberry Eradication.—Dr. Stakman reported upon progress of the work of barberry eradication. Among other things he brought out the fact that barberries were much more numerous and more widely distributed than had been supposed, that they were quite universally rusted even on well-kept lawns, that in the northern United States, all cases of early infection of stem rust upon grains and grasses had been directly traceable to barberries and that the barberry campaign was succeeding in rapidly clearing the states from Ohio to Montana and from Missouri to Canada of this worthless shrub. He said that reports had come in indicating that 70 to 90 per cent. of the bushes were already out in North Dakota, South Dakota, Minnesota, Wisconsin, Iowa, Michigan, Nebraska and northern Illinois. The fact was also brought out that the common barberry has escaped from cultivation in some few places.

Dr. A. G. Johnson reported finding a hybrid of the common barberry which was infected. He emphasized three points: (1) Barberries spring up from the roots when dug up, if the work is not thoroughly done; (2) seedlings of barberries had been found badly infected; (3) barberries had been located in many obscure places. Mr. Dixon, of Wisconsin, reported on some work upon overwintering of uredinia. He found no overwintering of uredinia in 125 stations visited every two weeks during winter and spring. Dr. Stakman stated that this had also been the experience of various other field scouts both this year and last.

Dr. Coons reported good progress in Michigan and stated that the strong arm of the law was needed to complete the work. All barberries had been removed which could be removed by publicity work. He also stated that no stem rust had been observed until after infection had become common upon barberries.

Professor Selby reported good progress from Ohio. He stated that the attitude of the people in general was to wait for infection.

Professor Jackson stated that the scouting work in Indiana had been confined to the northern part of the state.

Dr. Stevens and Dr. Anderson were both present from Illinois. They stated that infection was abundant in Illinois in the northern part, and down the Mississippi River as far as Rock Island.

Stem Rust Studies.—Dr. Stakman reported very